Analysis of Isocyanates Using the ASSET™ EZ4-NCO Dry Sampler

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Introduction

Isocyanates are used as a raw material to produce a number of products such as automotive paints, rigid and spray foam insulation and furniture, to name a few. Personal exposure can occur while the products made with isocyanates are being applied, or when the materials are removed by grinding or thermal degradation. Workers who are exposed to these compounds are at risk for respiratory disorders and asthma. The highly reactive nature of the isocyanate compounds and the low occupational exposure limits put high demands on both sampling and analytical techniques for monitoring of isocyanates in air.

The most common devices for sampling isocyanates are impingers and impregnated filters. Impingers are the least desired for personal sampling due to the risk of exposure to solvent vapors during sampling. There are also other issues such as glass breakage and difficulty shipping the needed reagents before and after sampling. Existing impregnated filter devices are safer for the worker to wear but have their own known issues, such as:

- Incomplete derivatization of particle bound analytes
- Insufficient capacity and/or breakthrough resulting in underestimation of isocyanate concentration
- Limited range of isocyanate compounds
- Field reagent addition and/or desorption necessary/ recommended
- Unstable reagents and limited shelf-life

ASSET EZ4-NCO sampler (**Figure 1**) uses dibutyl amine (DBA) derivatization of isocyanates according to ISO17734-1*; the DBA-derivatives are very stable and the derivatization takes place during air sampling and does not require the use of additional liquids and reagents. The special sampler design ensures that both the vapor phase and particulate isocyanates are captured and derivatized during sampling. ASSET samplers can be kept at room temperature as long as 4 weeks prior to extraction and analysis. The analysis of 10 isocyanates and di-isocyanate compounds can be performed simultaneously using LC-MS or LC-MS-MS detection methods.

Figure 1. ASSET EZ4-NCO Dry Sampler

In this study, we investigated the detection limits and the sensitivity of analysis after the ASSET samplers were spiked with a mixture of DBA-isocyanate derivatives representing an air concentration of 5 µg/m^3 at an assumed sample volume of 24 L (recommended flow range of the sampler is 0.1-0.25 L/min).

Spiking and Extraction of Isocyanates From The Sampler

The DBA-Isocyanate standard solution was used for spiking the ASSET sampler at 0.12 µg for each compound investigated; the extraction procedure was then applied. The procedure is briefly described in **Figure 2**. Internal Standards (Deuterated DBA-Isocyanates) are added prior to the extraction to get better precision for quantitation and to compensate for any change in the DBA-isocyanate concentration during the extraction process.

Figure 2. Summarized Procedure for Extraction of DBA-Isocyanate Derivatives from the ASSET Sampler

Remove the filter medium from ASSET sampler and place into a test tube

⌄

Add 1 mM sulfuric acid, methanol, toluene and deuterated I.S.

⌄

Shake, sonicate and centrifuge

⌄

Collect the top toluene layer, add more toluene and repeat the extraction

⌄

Collect all toluene layers and evaporate to dryness

⌄

Dissolve the sample in 1 mL acetonitrile for LC-MS(-MS) analysis

LC-MS Analysis

Calibration standards are prepared by spiking a matrix solution with both DBA-isocyanates and deuterated internal standards. The calibration standards are then taken through the extraction procedure. The concentrations used for calibration in this study were 5-280 ng/mL with respect to underivatized isocyanates. The I.S. concentration used in the final sample was 20 ng/mL. **Table 1** lists the quantitation limits that were established based on the concentration of the extracted samples by using LC-MS and LC-MS/MS.

*ISO 17734-1: Determination of organonitrogen compounds in air using LC-MS Part 1: Isocyanates using dibutylamine derivatives

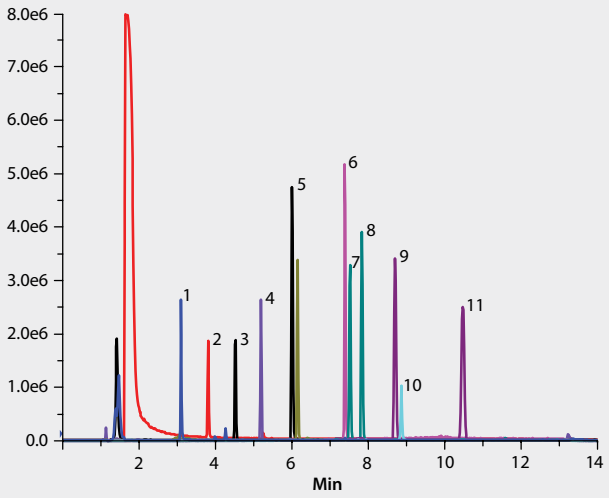
Table 1. Limits of Quantitation for LC-MS and LC-MS/MS Methods

Compound	MS (ng/mL)	MS/MS (ng/mL)
ICA	5.00	1.000
MIC	25.00	3.000
EIC	15.00	4.000
PIC	10.00	10.000
PhI	3.00	0.400
HDI	2.00	0.500
2,6-TDI	3.00	0.030
2,4-TDI	3.00	0.030
IPDI-1	4.00	0.400
IPDI-2	4.00	0.400
MDI	3.00	2.000

Figure 3. Chromatogram of DBA Standard (equivalent 0.20 µg/mL each underivatized monomer)

column: Ascentis® Express C18, 15 cm x 4.6 mm, 2.7 µm particles (53829-U)
mobile phase: (A) 5:95 acetonitrile:water w/ 0.05% formic acid; (B) 95:5 acetonitrile:water w/ 0.05% formic acid
gradient: 40% to 70% B in 3 min; 70% to 90% B in 2 min; hold at 90% for 6 min, 90% to 40% in 0.1 min, hold at 40% for 3.9 min
flow rate: 1 mL/min
column temp.: 35 °C
detector: AB3200 QTrap MS, ESI(+), SIM
injection: 2 µL

1. Isocyanic acid (ICA)
2. Methyl isocyanate (MIC)
3. Ethyl isocyanate (EIC)
4. Propyl isocyanate (PIC)
5. Phenyl isocyanate (PhI)
6. Hexylmethylene diisocyanate (HDI)
7. 2,6-Toluene diisocyanate (2,6-TDI)
8. 2,4-Toluene diisocyanate (2,4-TDI)
9. Isophorone diisocyanate (isomer 1) (IPDI-1)
10. 4,4'-Methylenediphenyl diisocyanate (MDI)
11. Isophorone diisocyanate (isomer 2) (IPDI-2)



Recoveries

Overall, the recoveries for spiked filter sample with the DBA derivatives were consistent ranging 77.9-125% with RSD's <16% for MS and averages of 95.0-117% with RSD's < 9% for MS/MS analytical methods. Spiking the sampler with 0.12 µg of each isocyanate-derivative would equate to 5 µg/m^3 air concentration if a 24 liter air sample was taken.

Table 2. Average Recovery (%RSD) from 0.12 µg Spiked Sampler (n=3)

Compound	MS (ng/mL)	MS/MS (ng/mL)
ICA**	98% (5)	117% (1)
MIC	101% (2)	97% (3)
EIC	95% (5)	95% (3)
PIC	78% (15)	102% (8)
PhI	95% (4)	100% (4)
HDI	125%	116% (2)
2,6-TDI	108% (13)	101% (4)
2,4-TDI	107% (6)	102% (4)
IPDI-1	102% (4)	103% (5)
IPDI-2	102% (4)	100% (2)
MDI	89% (13)	111% (9)

** Recoveries were corrected for a small amount of ICA found in the filter blank sample.

Conclusions

We investigated the performance of the LC-MS and LC-MS-MS methods in the analysis of isocyanates using the new ASSET™ EZ4-NCO Dry Sampler. We found that the analytical method can successfully reach the quantitation limit for most isocyanates of 5 ng/mL in the final sample when LC-MS-MS analysis was used and the quantitation limit of 10 ng/mL when LC-MS analysis was used. These numbers can translate, respectively, to 0.21 µg/m^3 and 0.42 µg/m^3 in air if a 24 liter air sample was taken. Both LC-MS and LC-MS-MS analysis gave reasonably low LOQs for the method. All 11 compounds were well-resolved chromatographically using a 15 cm Ascentis Express C18 column. The acceptable recoveries for the isocyantes demonstrated the overall efficient performance of the extraction and analytical method.

Featured Products

Description	Qty.	Cat. No.
Sampling Device		
ASSET EZ4-NCO Dry Sampler	10	5027-U
	50	5028-U
Analytical Column		
Ascentis Express C18,15 cm x 4.6 mm, 2.7 µm particles	1	53829-U
Analytical Standards (in acetonitrile:methanol, 99:1, varied conc)		
DBA Isocyanate Mix	6 x 1 mL	40141-U
Isocyanic acid-di-n-butylamine (ICA-DBA), 1 µg/mL Ethyl isocyanate-di-n-butylamine (EIC-DBA), 1 µg/mL Hexamethylene diisocyanate-2(di-n-butylamine) (HDI-2(DBA)), 1 µg/mL Isophorone isocyanate-2(di-n-butyl amine) isomer 1 (IPDI-2(DBA)), 1 µg/mL Isophorone isocyanate-2(di-n-butyl amine) isomer 2 (IPDI2-2(DBA)), 0.4 µg/mL 4,4'-Methylenediphenyl diisocyanate-2(di-n-butylamine) (4,4'-MDI-2(DBA)), 1 µg/mL Methyl isocyanate-di-n-butylamine (MIC-DBA), 1 µg/mL Phenyl isocyanate-di-n-butylamine (PhI-DBA), 1 µg/mL Propyl isocyanate-di-n-butylamine (PIC-DBA), 1 µg/mL 2,4-Toluene diisocyanate-di-n-butylamine (2,4-TDI-2(DBA)), 1 µg/mL 2,6-Toluene diisocyanate-2(di-n-butylamine) (2,6-TDI-2(DBA)), 1 µg/mL		
d_9-DBA Isocyanate Internal Standard Mix	6 x 1 mL	40142-U
Isocyanic acid-di-n-butylamine-d_9 (ICA-DBA- d_9), 1 µg/mL Ethyl isocyanate-di-n-butylamine-d_9 (EIC-DBA-d_9), 1 µg/mL Hexamethylene diisocyanate-2(di-n-butylamine-d_9) (HDI-2(DBA-d_9)), 1 µg/mL Isophorone diisocyanate-2(di-n-butylamine-d_9) isomer 1 (IPDI-2(DBA-d_9)), 1 µg/mL Isophorone diisocyanate-2(di-n-butylamine-d_9) isomer 2 (IPDI2-2(DBA-d_9)), 0.28 µg/mL 4,4-Methylenediphenyl diisocyanate-2(di-n-butylaine-d_9) (4,4'-MDI-2(DBA-d_9)), 1 µg/mL Methyl isocyanate-di-n-butylamine-d_9 (MIC-DBA-d_9), 1 µg/mL Phenyl isocyanate-di-n-butylamine-d_9 (PhI-DBA-d_9), 1 µg/mL Propyl isocyanate-di-n-butylamine-d_9 (PIC-DBA-d_9), 1 µg/mL 2,4-Toluene diisocyanate-2(di-n-butylamine-d_9) (2,4-TDI-2(DBA-d_9)), 1 µg/mL 2,6-Toluene diisocyanate-2(di-n-butylamine-d_9) (2,6-TDI-2(DBA-d_9)), 1 µg/mL		
DBA Isocyanates Mix Kit Includes 1 mL of 40141-U and 1 mL of 40142-U listed above	2 x 1 mL	40143-U